SYSTEM AND METHOD FOR COMBUSTION ENGINES

The present invention relates to vehicle combustion
engines and to a method and a system for improving combustion
in a combustion chamber of a combustion engine.

BACKGROUND OF THE INVENTION

Fuels for spark-ignition engines must conform to
stringent specifications regarding their volatility
characteristics to ensure satisfactory operation of
combustion engines. The fuel must contain a large enough
fraction of highly volatile components for good cold starts
of the engine, but the volatility must not be so high as to
impair operation and starting, or during driving, when the
engine is warm.

The volatility has a major influence of the wall-wet
dynamics in the cylinders in for example port-injected
gasoline engines. A fuel having different fuel volatility
will result in a changed air-to-fuel ratio, which may lead to
a non-desired combustion.

SUMMARY OF THE INVENTION

An aspect of the invention relates to the problem of
achieving an improved operation of a combustion engine.

This object is achieved by a method including:
receiving a measured air-to-fuel ratio value, receiving at
least one estimated air-to-fuel ratio value, said air-to-fuel
ratio estimate being generated in dependence of a
predetermined fuel deposit factor, establishing a fuel
volatility value in dependence of said measured air-to-fuel
ratio value and said air-to-fuel ratio estimate, and
controlling combustion in dependence of said fuel volatility

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value.

By establishing the volatility of the fuel, it is possible to compensate the wall-wet functions and/or models in the Engine Control Unit and reach an improved combustion quality. Thereby, the engine is automatically optimised even for fuels that significantly differs from the fuel for which the engine was originally adapted.

According to an embodiment said measured air-to-fuel ratio value is compared to said air-to-fuel ratio estimate, and said a fuel volatility value is generated in dependence of said comparison. This advantageously allows for adapting the combustion control in dependence of the actual fuel quality, which is currently used for the engine. Thereby, commercial fuel from markets world-wide may be used, even though the fuel quality may vary within a wide range.

Since an aspect of the invention is based on comparisons between mutually different estimated air-to-fuel values and a measured value as to establish a fuel volatility value, it is preferred to use a large number of estimated air-to-fuel ratio values in the model. A large number of estimated air-to-fuel ratio values would increase the accuracy of the established fuel volatility value, which leads to a better combustion control of the engine

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described in greater detail with aid of the enclosed drawings in which:

Figure 1 is a block diagram depicting a vehicle drivetrain and a control system therefore.

Figure 2 schematically is illustrating an internal combustion chamber and a control system therefore.

Figures 3a and 3b are illustrating a block diagram of a system according to an aspect of the present invention.

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Figure 3c is illustrating a block diagram of a system according to yet an aspect of the present invention.

Figures 4a and 4b are flow charts depicting a method according to an aspect of the invention. Figure 4c shows in greater detail a method according to an aspect of the invention.

Figure 5 is a flow chart of depicting a method according to an aspect of the invention.

Figure 6 shows a flow chart of a method according to yet an aspect of the invention.

Figure 7 is a block diagram illustrating a microcomputer, which may be used in the present invention.

Figures 8a and 8b are illustrating a block diagram of another aspect of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 shows schematically a vehicle drivetrain 1 and a control system therefore. The drivetrain comprises an internal combustion engine 2 and a drivetrain member in the form of a gear unit 4. A shaft 5 is coupled between the engine 2 and the gear unit 4, which shaft 5 works as force transmitting means. A transmission output shaft 7 drives the wheels of the vehicle for its propulsion.

A control unit 8, such as an Engine Control Unit (ECU), is adapted to receive signals from an accelerator member 9 of the drivetrain, said member 9 may be an accelerator pedal, and to receive condition parameters, such as engine condition parameters, from sensors 11, (11a, 11b, 11c and 11d), and to send signals to control the operation of the engine. A method according to the invention only needs input signals that are used today, i.e., no extra sensors are needed. The sensors 11a-d may be adapted for communication with the control unit 8 in various manners. Sensors may, such as 11a, be arranged between the control unit 8 and other control units, in this embodiment a Transmission Control Unit

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(TCU) 10. Alternatively, sensors 11b may be adapted for communication with the control unit 8 directly. Further, as shown in the figure, sensors 11c may be connected to both the control unit 8 and other vehicle drivetrain members, for example the engine 2. Furthermore, sensors 11d, may be adapted for communication with internal control units, such as the TCU 10, which may pre-treat data detected by sensors 11d and thereafter send relevant data to the control unit 8. Sensors 11a-d may include e.g., temperature sensors, throttle potentiometer, throttle switch, starter switch, Lambda sensor, pressure sensors and coolant temperature sensors. The control unit 8 processes signals from said sensors and controls different functions in respective drivetrain members.

The control unit 8 is adapted for communication with the Transmission Control Unit 10 (TCU). The TCU 10 is further particularly adapted to receive signals corresponding to transmission condition parameters and to send control signals to the transmission 4.

Figure 2 schematically is illustrating an internal combustion chamber in an engine of the vehicle drivetrain. Shown in the figure a reference number 20 denotes a cylinder block and reference number 21 a cylinder in which a piston 22 is displaceably mounted. The piston 22 may be connected with the crankshaft 5 (shown in Figure 1) by a connecting rod 23 rotatably mounted in a crankcase 24 of the cylinder block 20. A lower frame bearing bridge and an oil pan, which together close the crankcase, are omitted from Figure 2.

A throttle body 221 is adapted to feed air, via an intake air pipe 220 and an intake manifold 225a, to a channel 226a. The throttle body 221 could be the compressor of a turbocharger or supercharger. Alternatively, the engine could be naturally aspirated. A fuel injector 222 is adapted to supply fuel into the channel 226a, which channel connects the intake manifold 225a with a valve 27a. The control unit 8 is adapted for communication with the fuel injector 222 and

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to control the amount of delivered fuel into the channel 226a. The control unit 8 is also adapted for communication with the throttle body 221 and to control the amount of delivered air into intake manifold 225a.

Air and fuel is mixed in the channel 226a to an air-and-fuel mixture 29. The air-and-fuel mixture 29 is fed to valves 27a via the channel 226a and further supplied into the cylinder 21 via said valves 27a. The intake manifold may be connected to a plurality of valves 27a, even though just one connection is shown in the figure. The number of valves 27a in each of the cylinders of the engine 2 may be a plurality of valves, even though only one valve 27a is illustrated in Figure 2. The control unit 8 is adapted for communication with the valve 27a and to control the air-and-fuel mixture supply into the cylinder 21. The injection, through the valves 27a, of the air-and-fuel mixture 29 is controlled as to disperse as evenly as possible in the cylinder barrel. For initialisation of combustion of the air-and-fuel mixture 29 in the cylinder barrel, a spark plug 28 is arranged to enable the provision of sparks in the cylinder. The sparks generated by the spark plug 28 may be controlled by the control unit 8.

At and in the inlet valve 27a, the dynamics of illustrated fuel droplets are shown heavily enlarged at 200. This dynamics is of particular interest for the present invention. By estimating the wall-wet dynamics during engine load changes, using a model-bank algorithm, fuel volatility can be identified in real time.

The air-and-fuel mixture injected into the cylinder 21 may be subject to phase transformation in different stages of the Otto-cycle. Some of the injected fuel may be attached to the inlet port wall. The fuel attached to the wall, regardless of what phase it may be in (e.g., fluid or gas), may in a later stage, e.g. when de-attached, influence the present air-to-fuel ratio value in the cylinder 21, also referred to as λ-value.

A lambda sensor 210 is provided for generating a measured relative air-to-fuel ratio value. Lambda is the actual air-to-fuel ratio divided by the air-to-fuel ratio at a stoichiometric proportion. Stoichiometric proportion is

5 the ratio of fuel to air that would theoretically completely consume both the fuel and air. The term air-to-fuel ratio is used throughout this specification since it can be easily computed from the relative air-to-fuel ratio, lambda, and the stoichiometric air-to-fuel ratio, which is a known quantity

10 for a given fuel. The Lambda sensor may be placed in an exhaust manifold 225b. A channel 226b connects an exhaust valve 27b and the exhaust manifold 225b. Said manifold has an

exhaust pipe 228, in which exhaust gases from the cylinder 21

15 are diverted via the exhaust valve 27b. The combustion chamber may comprise a plurality of exhaust valves 27b, even though just one valve 27b is shown in the figure. The control unit 8 is adapted for communication with the valve 27b and to control said valve 27b. The Lambda sensor is

20 adapted to communicate with the control unit 8, and in particular to transmit a measured air-to-fuel ratio value to said control unit 8. The Lambda sensor may measure an average of air-to-fuel ratio of several cylinders of the engine.

25   Figure 3a schematically illustrates an embodiment of a system according to the invention. The model bank method is adapted to identify the wall-wet dynamics in the inlet ports of the vehicle drivetrain, and in particular to identify the deposit factor X so as to estimate the

30 - volatility.

          Sensors 11a-d (Figure 1) are adapted to detect and transmit input data to the control unit 8 of the vehicle drivetrain, via a data bus 320. The input data comprises data, such as in-cylindrical injected fuel amount 301, in-

35 cylindrical air amount 302, engine speed 303, engine load 304, by a lambda sensor measured lambda value 305, coolant

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temperature 306, etc. Data bus 320 may transmit data from sensors 11a-d, is illustrated in Figure 3b showing a few examples of input data (301-306). It should be understood that a plurality of other relevant data may be transmitted

5 from sensors 11a-d via the data bus 320.

The data may be processed to desirable format in anyone of the sensors 11a-d, which is of immediate interest. Alternatively, the data is transmitted to the control unit 8 and processed there. For example, the detected signal may be

10 transformed from analogue to digital format by an A/D-converter integrated in respective sensor, or in the control unit 8.

The control unit 8 comprises a volatility generator 300 and a combustion controller 360. The volatility

15 generator 300 and the combustion controller 360 are adapted for communication with each other.

The data bus 320 transmits the input data in parallel to a number N $\left(1 \leq i \leq N, i \in Z^+\right)$ of engine models EM_1-EM_N, which provide a model bank. Z+ means positive integers, the

20 number of engine models are thus N and i represents any positive integer between 1and N. Each engine model EM_i comprises a calculator device adapted to generate an air-to-fuel ratio value λ_i. According to one embodiment the engine models are identical in all aspects but one. Each engine

25 model uses a unique predetermined deposit factor value X_i in the calculation process. For example, the engine model EM_1 may have a unique predetermined deposit factor value X_i which equals 0.01 ($X_1 = 0.01$). In response to signals from the sensors 11a-d in combination with the unique deposit factor

30 value it generates a corresponding air-to-fuel ratio λ_1, as shown in Figure 3a. The other engine models EM_2-EM_N of the model bank work in a corresponding manner. Each one of the individual engine models EM_i use the same input data but on the basis of individual and mutually different predetermined

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deposit factors, each engine model generates a unique air-to-fuel ratio value λ_i. Said unique air-to-fuel ratio values are sent to process unit 330. Said unique air-to-fuel ratio values are also referred to as air-to-fuel ratio estimates.

5   Process unit 330 is adapted to receive input data D1-DN from the engine models EM_1-EM_N in data ports P1-PN, respectively. The input data D1-DN may be signals 301-306. Further, a air-to-fuel ratio value sensor, preferably placed downstream the cylinders of the vehicle drivetrain 1, as

10   shown in Figure 2, is adapted to measure and transmit a measured value of the air-to-fuel ratio λ_{meas}, to the control unit 8.

The process unit 330 processes both the air-to-fuel ratio estimates and the measured air-to-fuel ratio value.

15   This may be performed in different ways. According to an embodiment of the invention the mutually different air-to-fuel ratio estimates are compared to the measured air-to-fuel value during engine load changes such that a best estimate of the actual deposit factor is obtained.

20   According to an aspect of the invention the comparison is based on in real time generated derivatives of the estimated air-to-fuel ratio value(s). At least one derivative of each estimated air-to-fuel ratio value may be calculated. The derivatives may be of one or several orders.

25   The derivatives may be calculated with respect to time, when the dynamics of the model is exited by a load change. The derivatives may be calculated with respect to other parameters, such as engine load and engine speed. Corresponding derivatives are calculated for the measured

30   air-to-fuel ratio value. The generated processed estimated air-to-fuel ratio value, which has the least integrated error during a certain time period compared with the generated processed measured air-to-fuel ratio value, is to be chosen as the best estimated value. The corresponding deposit

35   factor, which may be stored in ditto engine model, is

denominated output data X_i and is transmitted to process unit 350.

The deposit factor X_i is received in an input 337 of process unit 350. In the process unit 350 another comparison process is performed. The selected deposit factor X_i is delivered to an input 345 of process unit 350. The method according to the invention is particularly advantageous at cold start of the engine, or actually while the engine is cold. According to an embodiment, the engine temperature detected by sensor 11c, and the detected temperature value is delivered on input 340 to process unit 350.

According to an embodiment, there is provided a plurality of reference fuel models in the process unit 350. Input data is detected in real time by sensors 11a-d and transmitted to the control unit 8 via data bus 340 and taken into account in process unit 350. In dependence of said input data, e.g., engine temperature, said output data X_i is compared to at least one X-estimate of a reference fuel, which has been determined during calibration and stored in a memory (not shown) in process unit 350.

The process unit 350 further generates an estimation of the fuel volatility in dependence of said output data X_i and said at least one X-value of a reference fuel, which volatility estimate is transmitted as output V_E to an input 365 in a combustion controller 360 for further processing.

The volatility generator 300 comprises the features EM_1-EM_N, 330 and 350.

The combustion controller 360, may use the volatility estimate as to compensate wall-wet functions, used by the control unit 8 for controlling the engine 2, as to improve combustion quality in the cylinders of the engine's cylinders by transmitting control signals to the valves 27 and the spark plug 28.

Figure 3c illustrates an embodiment of the invention in which four different volatility generators 301, 302, 303

and 304 are fed by the data bus 320 as above. Also, a lambda
sensor for each cylinder is adapted to measure an air-to-fuel
ratio value in respective cylinder and transmit said value to
the corresponding volatility generator. According to this
5   embodiment, the volatility generators 301-304 are adapted to
communication with combustion controllers 361, 362, 363 and
364, respectively. The volatility generators 301-304
generate volatility estimates V_{E1}-V_{E4} and transmit these
estimates respective combustion controller, as shown in
10   figure. The combustion controllers 361-364 individually
controls a separate cylinder of the engine 2. Thus, in this
embodiment, the engine comprises four cylinders.

       Figure 4 is a block diagram illustrating an overview
of an engine model EM for identification of the wall-wet
15   dynamics according to an aspect of the invention.

       The wall-wet model is the Aquino model G_{ww}:

$$G_{ww}(s) = \frac{(1-X) \cdot \tau_{ww} \cdot s + 1}{\tau_{ww} \cdot s + 1}$$

where X is the portion of the injected fuel depositing on
the wall, referred to as deposit factor, as shown in Figure 2
20   at 200, and τ_{ww} is the evaporation time constant. Both X and
τ_{ww} depends on the volatility of the fuel as well as of, e.g.,
engine temperature, engine load and speed. These properties
are detected and transmitted as input data to the model and
taken into account at different calculation stages as 410,
25   420 and 430, respectively.

       The model of the gas dynamics G_{gd} in the cylinder of
the engine is:

$$G_{gd} = \frac{e^{-T_d \cdot s}}{\tau_{gd} \cdot s + 1}$$

where both the delay T_d and the time constant τ_{gd} is mapped
30   against engine load 304 and engine speed 303. Preferably,

the input signals M_a, M_f, 410, 420 and 430 are delayed with T_d to compensate for the time delay in the gas dynamics.

Figure 5 is a flow chart depicting a method of operating the control units shown in Figure 3a according to an aspect of the invention. In this embodiment, the combustion chamber is the cylinder 21, shown in Figure 2. The step s53 is to receive a measured air-to-fuel ratio value. The next step s55 is to receive a plurality of air-to-fuel ratio estimates, said air-to-fuel estimates being generated in dependence of a predetermined deposit factor. With reference to Figure 3a, each engine model Em_i-EM_N may generate mutually different air-to-fuel ratio estimates. Step s57 is to generate a fuel volatility value in dependence of said measured air-to-fuel ratio value and said air-to-fuel ratio estimate, and finally, step s58 is to control combustion in dependence of said fuel volatility value.

Figure 6 shows a flow chart of a method according to an aspect of the invention. Input data 301-306, among others, is detected in step s610 by sensors 11 a-d, as described above, and transmitted to the control unit 8 wherein the following steps are performed. Preferably, step s620 is performed by a plurality of engine models EM_i-EM_N, each engine model generating at least one estimate. Each of the generated air-to-fuel estimates is unique, based on the fact that each air-to-fuel ratio estimate is generated for a certain value of the deposit factor, as described above. In step s630, a value of current air-to-fuel ratio value in a cylinder is detected in step s630. This is also referred to as measured air-to-fuel ratio value. It is to be considered to be obvious for a person skilled in the art to realize that the method may be applied for all cylinders in the engine 2, provided that there is one Lambda sensor measuring air-to-fuel ratio values for each cylinder. Further, the created air-to-fuel ratio estimates (from step s620) and the measured (step s630) air-to-fuel ratio value are processed in step

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s640. This comparison takes place in step s650. According
to an embodiment, each air-to-fuel ratio estimate is compared
to the measured air-to-fuel ratio value and the estimate
whose value is nearest to the measured air-to-fuel ratio
value is chosen. This chosen air-to fuel-ratio estimate
corresponds to a certain deposit factor value. More
precisely that air-to-fuel ratio estimate, which is generated
in step s620 from a predetermined deposit factor. In step
s650, that deposit factor is selected. Input data, detected
in step s660 by sensors 11a-d, is needed for generating a
volatility estimate carried out in step s670. Said input
data comprises at least engine temperature and is used for
the estimation performed in step s670. The estimation is
performed by, for example, an identification method in which
the chosen deposit factor is compared with deposit factors of
reference fuels. In dependence of the generated volatility
estimate, the combustion in a combustion chamber is
controlled as to improve combustion quality in step s680.

According to another embodiment, step s650 compares
an integral value of the air-to-fuel ratio estimates and the
measured air-to-fuel ratio value.

According to another embodiment, step s650 compares
time-derivatives of the air-to-fuel ratio estimates and the
measured air-to-fuel ratio value as to enable to compare the
dynamics and reduce any offset error in the estimated air-to-
fuel ratio values

According to another embodiment, step s650 compares
an integral value of the air-to-fuel ratio estimates and the
measured air-to-fuel ratio value related to mapped
information in dependence of in step s610 detected data.

According to yet another embodiment, step s680 the
combustion in a plurality of combustion chambers are
controlled.

With reference to Figure 7, there is shown a diagram
of one way of embodying an apparatus 700. The above
mentioned control unit 8 may include an apparatus 700. The

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apparatus 700 comprises a non-volatile memory 720, a data
processing device 730 and a read/write memory 740. The
memory 720 has a first memory portion 750 wherein a computer
program, such as an operating system, is stored for
controlling the function of the apparatus 700. Further, the
apparatus 700 comprises a bus controller 770, a serial
communication port 771, I/O-means 772, an A/D-converter 773,
a time date entry and transmission unit 774, an event counter
775 and an interrupt controller 776. Even further, the
apparatus 700 comprises a data port 799.

The data processing device 730 may be embodied by,
for example, a microprocessor.

The memory 720 also has a second memory portion 760,
where a program for improving combustion quality in a
combustion chamber is stored. In another embodiment, the
program for improving combustion quality in a combustion
chamber is stored on a separate non-volatile recording medium
762. The program may be stored in an executable manner or in
a compressed state.

When, in the following, it is described that the
data processing device 730 performs a certain function, this
is to be understood that the data processing device 730
performs a certain part of the program which is stored in the
memory 760 or a certain part of the program which is stored
in the recording medium 762.

An internal clock 777, which is adapted to generate
clock cycle, pulses having a frequency of F MHz. The
internal clock 777 is coupled to the data processing means
730 by means of a data bus 781, and to the bus controller 770
by means of a data bus 780. The data processing device 730
may communicate with a data port 799 by means of a data bus
783. The memory 720 is adapted for communication with the
data bus 783 via data bus 785. The separate non-volatile
recording medium 762 is adapted to communicate with the data
processing device 730 via data bus 789. The read/write
memory 740 is adapted to communicate with the data bus 783

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via a data bus 785. Internal features 771-775 is fed by the internal clock 777 via a data bus 787 connected to the data bus 780, respectively (only showed for 775 in the figure). The bus controller 770 is fed directly by the data bus 780.

5   Further, the internal features 770-775 are adapted to communicate with the data bus 783 via a data bus 788 (only showed for 775 in the figure). The internal features 771-775 are adapted to communicate with the data bus 782 and each of the internal features 770-775 is adapted for communication

10   with an external unit by a bus 790, respectively (only showed for 775 in the figure).

       The methods described with reference to Figure 5 and 6 can be performed by the apparatus 700 by means of the data processing device 730 running the program stored in the

15   memory portion 760. When the apparatus 700 runs the program the method described with reference to Figure 5 and/or Figure 6 is executed. Thereby, the data processing device 730 is set up to wait for reception of input data 301-306 via data bus 320, such as measured air-to-fuel ratio value and input

20   data 340 on the data port 799, or in the I/O unit 710. When the data is received on the data port 799 said input data is temporarily stored in the read/write memory 740. When all the received input data have been temporarily stored, the data processing device is set up to perform the calculations

25   in a manner described above, such as a fuel volatility estimate is created.

       Figure 8 is illustrating a block diagram of yet an aspect of the invention.

       The features according to this aspect of the

30   invention are essentially functioning as the corresponding features in Figure 3a, except that each processor unit and each engine model EM_1-EM_N is a separate processor unit and not provided in one control unit 8.

Although the Figure 8 refers to microprocessors MP1-MPN it is to be understood that each device MP1-MPN may be embodied by an apparatus 700 as described with reference to Figure 7. Each microprocessor MP1-MPN comprises an engine

5   model Emi, respectively, and in accordance with Figure 3a.